12 MULTIPLE SURFACES

12.1 Choosing Survey Units

Three criteria mentioned in Section 2.2 constrained the choice of survey units:

(1) Classification by Contamination Potential: Survey units are composed of areas with similar usage, contamination, and remediation histories that determine the requirements of the final status survey.

(2) Congruity With the Dose Model Used: When the release criteria are dose-based, the survey unit configuration should be consistent with those assumed in the dose model used.

(3) Data Variability: The measurement data variability, σ, within survey units should be minimized so that acceptable decision error rates can be obtained with efficient sample sizes.

These criteria should guide the selection of survey units during the DQO process. However, there are situations in which it will necessary to balance the requirements of one criterion against the requirements of another. In those circumstances, one should be guided by the ultimate objective of the final status survey, namely to make the correct decision on whether the survey unit meets the release criterion.

As an example, consider a room with a concrete floor, one wall with tile, another with wallboard, a third with glass doors and windows, and a fourth with a large blackboard. There are at least five different surfaces, with potentially five different levels of residual radioactivity. Using only criteria (1) and (3), it might seem important to treat these as five distinct survey units. However, this is not only very inefficient, it may not even be the best solution. It is unlikely that any dose model treats a contaminated blackboard by itself. Modeling the five areas separately and combining the results may not be as faithful a representation as treating all the surfaces together as one contaminated room.

In this chapter, we discuss some of the factors to be considered during the DQO process to optimize the choice of survey units. We also introduce the concept of performing a *Sign test on paired measurements* when there are many diverse background materials present in a survey unit.

12.2 Combining Dissimilar Areas Into One Survey Unit

The primary disadvantages in separating very small areas of dissimilar contamination potential into distinct survey units are that such small survey units will not generally conform well to dose models, and that the resulting sample densities may be unreasonably high. The disadvantage of combining such areas is that the resulting survey unit will have a larger spatial concentration variability, requiring a larger sample size than if it were more uniform. However, the total sample size may not be as large as would be needed for separate survey units. This possibility can be investigated and resolved during the DQO process.

Consider an area such as shown in Figure 12.1: a 25 m by 100 m gravel parking lot, with a paved walkway across a 25 m by 100 m lawn to a building. The walkway covers about 400 m^2 of the lawn area. There are many ways that this area could be divided into survey units, depending on the level of expected contamination.

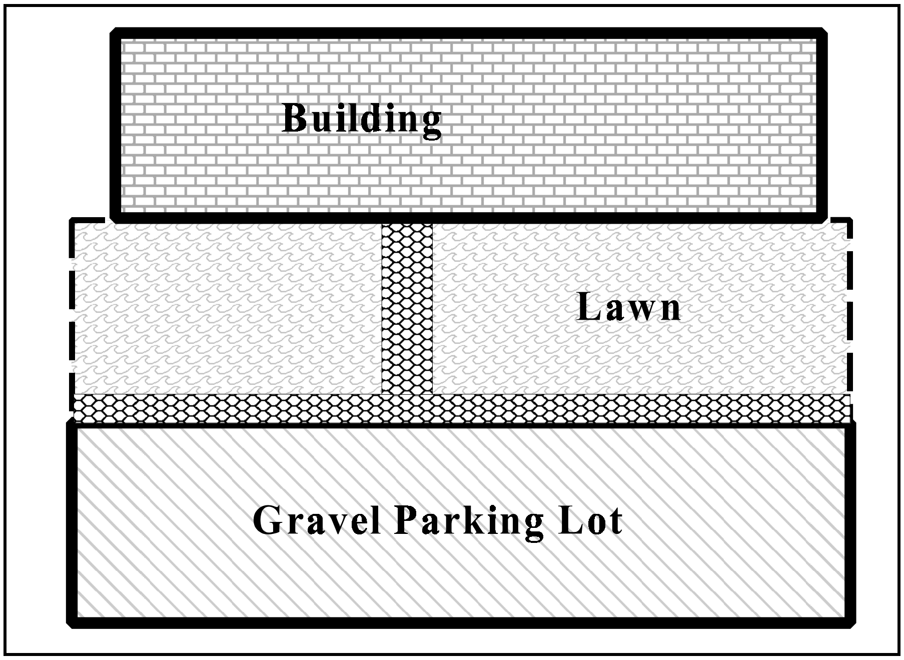

Figure 12.1 Example Survey Units: Case #1

Example Case #1: ^{60}Co was handled in hoods that were vented from the roof of the building. There is the possibility of a small amount of residual radioactivity, but at levels anticipated to be far below the DCGL. There is virtually no possibility of isolated elevated areas. All of the areas would be considered Class 2. Surface samples will be analyzed for ^{60}Co by Ge gamma spectrometry. The total area (5000 m^2) is within the parameters used by the dose model. Although it is possible that average residual radioactivity levels between the walk, the gravel, and the lawn are different, there is probably no reason to divide these areas into separate survey units. The walk may have almost no contamination because of runoff. Judgmental scans should probably be made along the edges of the walk and along the side of the building.

Example Case #2: The same as example 1, except that there had been a spill in the gravel parking lot. The area of the spill is shown as the dark area in Figure 12.2. During remediation of the spill, the surface material of the parking lot was disturbed by earthmoving equipment in the crosshatched area, approximately 1700 m^2. In this case, the disturbed area around the spill should be considered a Class 1 area. The surrounding area is still Class 2. There is the possibility of designating the entire parking lot as a Class 1 survey unit, but it might actually be more reasonable to include the uncontaminated part of the parking lot along with the other Class 2 areas. This will yield a higher sampling density in the actual contaminated area, even though it increases the variability in the Class 2 survey unit.

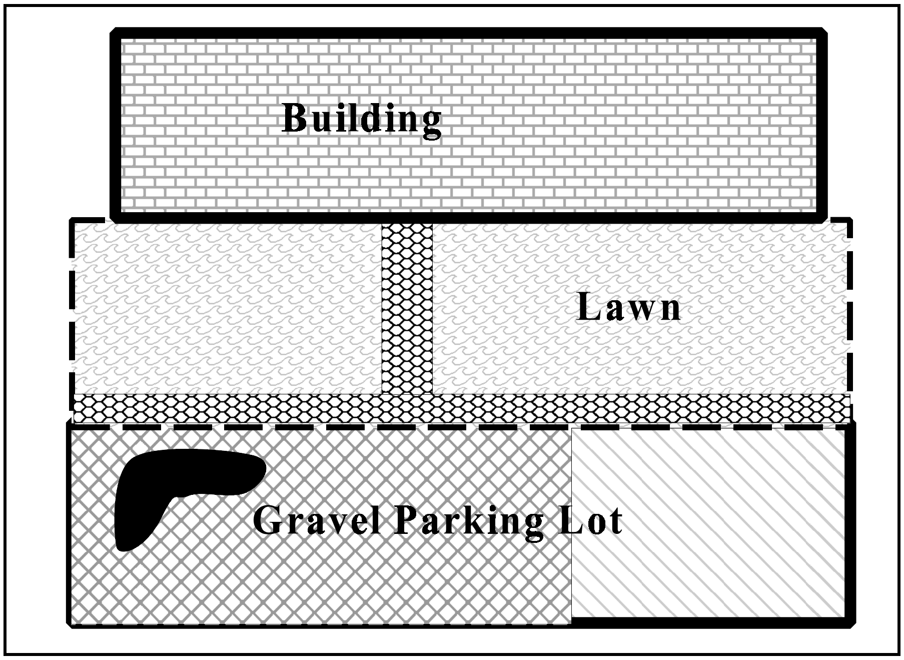

Figure 12.2 Example Survey Units: Case #2

Example Case #3: The same as example 2, except that the spill was on the walkway, as shown in Figure 12.3. The entire paved walkway was removed during remediation, and a substantial portion of the lawn and parking lot were disturbed in the process. The entire area (5000 m^2) should probably be designated Class 1, but is too large to contain only one survey unit. In this case, it may be reasonable to divide the area into two survey units— the former lawn area and the former parking lot. It is probably not practical, or prudent, to try to separate the small undisturbed parts of the lawn and the parking lot into a third survey unit.

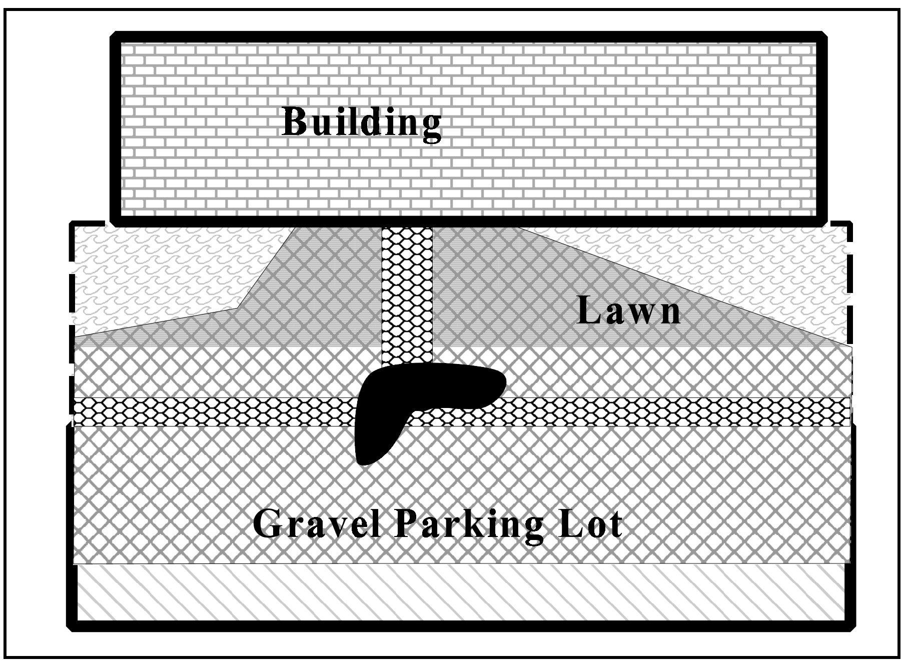

Figure 12.3 Example Survey Units: Case #3

These example cases are only meant to illustrate the considerations that may dictate how survey units may be designated, and what tradeoffs may be involved. What is actually done in any specific situation will depend on site-specific information from historical site assessments, and prior scoping, characterization, and remediation control survey results.

12.3 Using Paired Observations for Survey Units with Many Different Backgrounds

In this report, we have discussed using the Sign test for residual radioactivity that does not appear in background when radionuclide specific measurements are made, and otherwise using the WRS test. However, there are cases when one may wish to use the Sign test even when the radionuclide appears in background and/or radionuclide specific measurements are not made. An obvious instance would be when background is such a small fraction of the DCGL that including it is unlikely to affect the decision errors. An example would be ^{137}Cs residual radioactivity in an area where the concentrations from global fallout are small. It may be more cost-effective to simply compare the total ^{137}Cs concentration in the survey unit to the DCGL using the Sign test rather than to attempt to find a matching reference area.

Another case in which the Sign test may be more appropriate is when there are many different materials within what would otherwise logically be a single survey unit. As indicated at the beginning of this chapter, to divide such a survey unit into separate parts, each requiring its own reference area is not only impractical, but may be inconsistent with the dose models used to determine the DCGLs.

Consider once again, the example case #1 shown in Figure 12.1. Suppose the residual radioactivity of concern is ^{226}Ra rather than ^{60}Co. We will call this example case #4. When ^{60}Co was the concern, only the variability in a material's potential for retaining or accumulating this radionuclide was important. If ^{226}Ra is the concern, then the variability in the background concentration of ^{226}Ra in the materials is an additional, perhaps more important concern in forming survey units. In Figure 12.4, the same area as for case #1 is again shown, but with consideration of this additional factor.

With an eye towards potential differences in background ^{226}Ra, it becomes important that:

- The walkway was paved with different concrete at two different times.
- The parking lot was expanded using a different type of gravel.
- Part of the lawn was graded with fill from another location.
- Soil and mulch were used for the plant beds next to the building.

What were previously three potentially different survey units are now possibly as many as nine different survey units. The contamination potential is still Class 2, as in case #1, and on that basis alone this area might be designated as a single survey unit. This disparity of effort between case #1, using the Sign test for ^{60}Co, and case #4 using the WRS test for ^{226}Ra is tremendous.

Fortunately, there is a third option— to use the Sign test with paired observations. Each measurement in the survey unit is paired with an observation on a suitable reference material. The Sign test is then performed on the difference. The tradeoff is the higher variability of the differences compared to a single measurement.

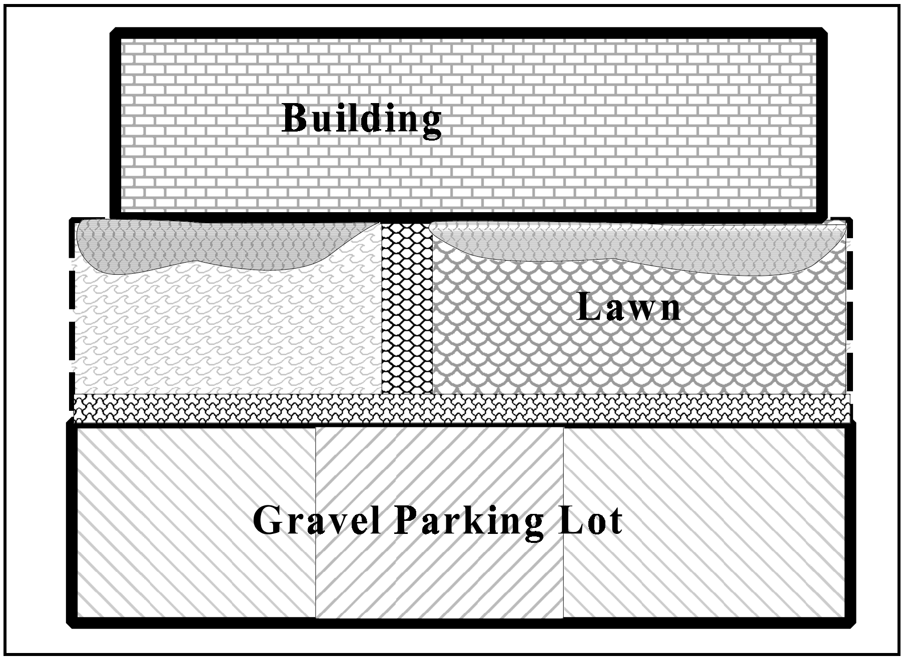

Figure 12.4 Example Survey Units: Case #4

In case #1, an estimate of the variability of the measurements from the survey unit, σ, is needed to determine the relative width of the gray area, Δ/σ, which then in turn is used to determine the required sample size, N. Suppose the survey unit measurements are designated by Y_i , for i = 1 to N. From each of these Y_i, a paired measurement, X_i , on an appropriate reference material is subtracted. The Sign test is performed on the difference $Y_i - X_i$. Thus it is the variability of these differences, $\sigma_{(Yi - Xi)}$, that is required in order to determine the required sample size. This variability has three components:

$$\sigma^2_{Y_i - X_i} = \sigma^2_{Y_i} + \sigma^2_{X_i} = \sigma^2_R + \sigma^2_{B_i} + \sigma^2_{X_i} \tag{12-1}$$

where

σ_{Xi} is the standard deviation of the measurements on the reference material,
σ_{Yi} is the standard deviation of the measurements in the survey unit,
σ_{Bi} is the standard deviation of the background in the survey unit material, and
σ_R is the standard deviation of the residual radioactivity in the survey unit.

If the reference material is truly representative, then $\sigma_{Xi} = \sigma_{Bi}$, so that

$$\sigma_{Y_i - X_i} = \sqrt{\sigma^2_R + 2\sigma^2_{B_i}} \tag{12-2}$$

Better precision may be possible if the average of m_j measurements made on the jth reference material is subtracted from each measurement from the survey unit made on that material.

The Sign test performed the differences:

$$Y_{j,k} - \overline{X_j} = \frac{Y_{j,k}}{m_j} \sum_{q=1}^{m_j} X_j \tag{12-3}$$

for $k = 1$ to n_j.

The variability of these differences is

$$\sigma_{Y_{i,j}-\overline{X_j}} = \sqrt{\sigma_R^2 + \sigma_{B_j}^2 + \sigma_{B_j}^2/n_j} = \sqrt{\sigma_R^2 + \left(\frac{n_j+1}{n_j}\right)\sigma_{B_j}^2} \tag{12-4}$$

Note that when ^{60}Co was the contaminant, the only component of variability was $\sigma = \sigma_R$.

To estimate the sample size needed for case #1, suppose the DCGL for ^{60}Co is 2 and that $\sigma_R = 0.7$. If the LBGR is set at 1, then $\Delta/\sigma = (2-1)/0.7 = 1.4$. For acceptable error rates of $\alpha = \beta = 0.05$, the sample size found in Table 3.2 is 20. Suppose, for the sake of illustration, that for case #4, the DCGL for ^{226}Ra is also 2, and $\sigma_R = 0.7$. If the ^{226}Ra background standard deviation is about 0.5, then standard deviation of the difference of matched pairs of measurements,

$$\sigma_{Y_i - X_i} = \sqrt{\sigma_R^2 + 2\sigma_{B_i}^2} = \sqrt{(0.7)^2 + 2(0.5)^2} = \sqrt{0.49 + 0.5} = \sqrt{0.99} \cong 1 \tag{12-5}$$

Thus, $\Delta/\sigma = 1$, and for the same LBGR of 1 and acceptable error rates of $\alpha = \beta = 0.05$, the sample size found in Table 3.2 is 29 measurements in the survey unit. An additional matching 29 measurements on reference materials are also needed, for a total of 58 measurements. To simplify the above calculations, a single estimate of the standard deviation of background measurements was used for all materials. It would be prudent to use the largest anticipated standard deviation. Note that no assumption about the average of the background concentrations in the different materials was made. This may vary considerably from one material to another.

Indeed, if the average concentration does not vary significantly, it would be better to perform the WRS test using a reference area with a composition that is reasonably well-matched to the survey unit. Suppose in case #4, that the average concentrations of ^{226}Ra did not vary much. Then the standard deviation of background in the reference area is still about 0.5, and the variability in the survey unit is simply

$$\sigma_{Y_i} = \sqrt{\sigma_R^2 + \sigma_{B_i}^2} = \sqrt{(0.7)^2 + (0.5)^2} = \sqrt{0.49 + 0.25} = \sqrt{0.74} \cong 0.86 \tag{12-6}$$

Thus, $\Delta/\sigma = 1.155$, and for the same LBGR of 1 and acceptable error rates of $\alpha = \beta = 0.05$, the sample size found by interpolating in Table 3.3 is about 26 measurements each required in the survey unit and reference area for a total of 52 measurements. The WRS test requires fewer measurements. An equivalent observation is that for the same number of measurements, the WRS test has greater power. The essential difference is whether the reference measurements can be considered independent of the survey unit measurements, or whether they must be matched together according to material type.

Notice that Equations 12-2, 12-4, and 12-6 differ primarily in the factor multiplying σ_B^2. Using the Sign test with a single matched reference measurement, this factor is 2. Using the WRS test, this factor is 1. If the mean of n_j measurements on the jth material is used this factor is $(n_j + 1)/n_j$. This equals 2 when $n_j = 1$, and approaches 1 as n_j becomes large.

The question remains as to how the measurements should be taken in the survey unit and from the reference materials. The measurements in the survey unit should be taken according to the regular procedure recommended for that class of survey unit, i.e., on a random start systematic grid for Class 1 and Class 2, and randomly for Class 3. This is essentially the same as sampling according to the proportional area of each material in the survey unit. Matching reference area samples should be taken randomly on the chosen reference material.